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# Environmental Engineering for the 21st Century: Increasing Diversity and Community Participation to Achieve Environmental and Social Justice

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**Abstract**

Communities of color are disproportionately burdened by environmental pollution and by obstacles to influence policies that impact environmental health. Black, Hispanic, and Native American students and faculty are also largely underrepresented in environmental engineering programs in the United States. Nearly 80 participants of a workshop at the 2019 Association of Environmental Engineering and Science Professors (AEESP) Research and Education Conference developed recommendations for reversing these trends. Workshop participants identified factors for success in academia, which included adopting a broader definition for the impact of research and teaching. Participants also supported the use of community-based participatory research and classroom action research methods in engineering programs for recruiting, retaining, and supporting the transition of underrepresented students into professional and academic careers. However, institutions must also evolve to recognize the academic value of community-based work to enable faculty, especially underrepresented minority faculty, who use it effectively, to succeed in tenure promotions. Workshop discussions elucidated potential causal relationships between factors that influence the co-creation of research related to academic skills, community skills, mutual trust, and shared knowledge. Based on the discussions from this workshop, we propose a pathway for increasing diversity and community participation in the environmental engineering discipline by exposing students to community-based participatory methods, establishing action research groups for faculty, broadening the definition of research impact to improve tenure promotion experiences for minority faculty, and using a mixed methods approach to evaluate its impact.

***Keywords:*** classroom action research; community-based participatory research; diversity; engineering education; environmental justice

## Introduction

The National Academies of Sciences, Engineering, and Medicine (NASEM, 2018) established five grand challenges for environmental engineering, which are to (1) sustainably supply food, water, and energy; (2) curb climate change and adapt to its impact; (3) design a future without pollution or waste; (4) create efficient, healthy, and resilient cities; and (5) foster informed decisions and actions that require both regulatory and behavioral changes. The report also emphasized that addressing each of these challenges requires a ''keen awareness of the needs of people who have historically been excluded from environmental decision making'' (NASEM, 2018, pg. 6). This includes communities of color, many of whom experience a disproportionate burden of disease from exposure to environmental pollutants (Levenson, 2020; Romero, 2020), which increases vulnerability to diseases such as COVID-19 (Wu *et al.*, 2020).

These communities, however, also face obstacles to participate in decision-making about policies affecting environmental health (Freudenberg *et al.*, 2011). An additional challenge is the transformation of science research from a paradigm that performs research for and with communities to one that equips underrepresented groups to perform the research themselves (Morgensen, 2012; Smith, 2012; Widianingsih and

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Mertens, 2020). Similarly, the goals of building capacity and expanding opportunity can unintentionally impose deficit-based models (Bernal, 2002; Hyett *et al.*, 2020) that run the risk of perpetuating themes of marginalization or disadvantage.

Community-based participatory research (CBPR), which engages community and academic partners as *equitable collaborators* in research, ideally with a certain level of cultural competence (O'Toole *et al.*, 2003; Briscoe *et al.*, 2009; Ross, 2010), provides a mechanism for also achieving environmental justice. CBPR has been used effectively in the health sciences (O'Fallon and Dearry, 2002; Nyden, 2003; Cook, 2008). For example, Loh *et al.* (2002) describes a collaboration of environmental justice, government, and research groups coming together to develop a real-time air pollution monitoring system and advocating for alternative fuel buses and other clean air measures.

Conducting CBPR in engineering expands the benefits to society and knowledge generation because communities and researchers can also co-create new technology in response to community needs. For example, in Champion *et al.* (2017a), community and researchers worked together to identify the most appropriate heating option for the Navajo Nation, taking into account perception, cultural, and technical factors. The recommendation was a dual (wood/coal) burning stove that was subsequently designed, certified, implemented, and evaluated in the community (USEPA, 2018; Chang *et al.*, 2019; Chang, 2019). The voluntary Carnegie Community Engagement Classification for institutions of higher learning has guided university efforts toward increased and improved community partnerships (Ersing *et al.*, 2007); however, only 46% of institutions with environmental engineering programs accredited by the Accreditation Board for Engineering and Technology (ABET) are currently classified.

Black, Latinx, and Native American students and faculty are also underrepresented in environmental engineering programs at universities and colleges compared with national demographics (Blaney *et al.*, 2016, 2018), posing an additional challenge for the field as it attempts to work and build trust with communities of color. Since the American Society of Civil Engineers endorsed ENVISION™ credentialing for sustainable infrastructure, and supported implementation of the civil engineering aspects of the United Nations' Sustainable Development Goals (SDGs), the recognition of community-engaged work has also grown in many departments with environmental engineering faculty and students.

There are environmental engineering faculty that currently conduct community-engaged work (both on research and teaching fronts). However, in other health-related fields (outside of environmental engineering), it has been observed that the use of community-engaged research methods is not valued as highly as traditional research in tenure and promotion processes. For example, a survey of 675 faculty across three universities within a clinical and translational sciences institute (Marrero *et al.*, 2013) revealed that faculty opinions were split (nearly 50/50) about whether community-engaged research scholarship was recognized and rewarded in review/tenure/promotion (RTP) processes at their institutions. However, in the same study, most faculty respondents disagreed or strongly disagreed with the following statements: (1) that community-engaged research scholarship was explicitly included in RTP policies and procedures; (2) that the RTP process encouraged publication in outlets that regularly disseminate community-engaged research; and (3) that RTP committees understood the definition, nature, documentation, and assessment of community-engaged research scholarship.

A survey of 59 faculty at institutions funded with National Institutes of Health (NIH) Clinical and Translational Science Awards (Nokes *et al.*, 2013) revealed confusion about the definition of community-engaged scholarship and persisting perceptions of barriers about its value in RTP decisions at their institutions. Goldberg-Freeman *et al.* (2010) reported that 90% of surveyed health researchers at one institution agreed that community involvement improved the relevance of their research, but less than half admitted that they had actually done so; respondents from this study reported wanting more institutional support for such activities.

This is all consistent with findings from in-depth interviews with 22 faculty at Johns Hopkins using CBPR, which revealed persistent challenges with existing academic incentive structures (Kennedy *et al.*, 2009). For instance, policies such as placing a high value on single-author publications can present challenges for faculty using CBPR (Strickland, 2006). Given these previous findings from health-related fields, as well as several perspectives and policy forum publications that elaborate similar sentiments (e.g., Nyden, 2003; Calleson *et al.*, 2005; Teufel-Shone, 2011; Chung *et al.*, 2015), it is plausible to anticipate that environmental engineering scholars who use CBPR may confront similar challenges earning tenure and promotions.

This article summarizes findings from a 1-day workshop held at the Association of Environmental Engineering and Science Professors (AEESP) Conference in Tempe, AZ, in May 2019 titled, "Environmental Engineering for the 21st Century: Increasing Diversity and Community Participation to Achieve Environmental and Social Justice." The daylong workshop was attended by nearly 80 participants. Approximately half the participants were environmental engineering and science faculty, and the other half consisted of postdocs, graduate and undergraduate students, and community members outside academia attending the conference. The workshop was open to anyone who registered for the conference, including non-AEESP members. The morning featured presentations about trends in the demographics of environmental engineering students and faculty in the United States and a discussion about the use of CBPR by minority faculty (Champion *et al.*, 2017a; 2017b; Li *et al.*, 2018; Chang, 2019).

In facilitated group discussions, participants were asked to brainstorm:

- Existing factors for success in academia (i.e., "business as usual"), and "ideal" factors that would lead to success in a more diverse academia,
- Examples of the overlapping challenges of underrepresentation in environmental engineering in higher education and environmental challenges that affect society, and
- Approaches to reverse underrepresentation in environmental engineering at colleges and universities.

To facilitate discussions, participants were seated at tables with $\sim$10–15 people each. After a short icebreaker activity, each table was provided with small post-it notes and markers. To encourage equitable participation, including from individuals not comfortable speaking in front of their group, participants were asked to independently think and then write down their comments about the three topics listed previously. The notes were anonymously collected and posted onto a large poster board. Then, a facilitator from each table read out the comments and led a table discussion, whereas the post-it notes were organized according to emergent themes. At the end of the morning session, a facilitator from each table reported the group's findings back to the larger audience.

The afternoon started with flash talks ( ~2 min each) given by 16 participants, including an undergraduate student, a graduate student, a postdoc, a community member, and faculty from all ranks. Some participants were invited to record their talks before the workshop, but everyone was invited to participate, if interested. The flash talk presenters were asked to highlight community-based or other work they were doing to help reduce inequities in their communities and institutions.

After these talks, participants worked in three different breakout groups to discuss ideas for increasing diversity and community participation in environmental engineering. Each group focused on one of the following three themes: (1) exposing underrepresented students to the field of environmental engineering; (2) improving experiences for minority faculty doing community-based research; and (3) evaluating the impact of community-based research on participants and members of society. Breakout group discussions were led by a facilitator, and participants recorded their ideas on large posters.

After the breakout sessions, each poster was placed in the main workshop room. One or two rapporteurs from each group stayed with their poster, whereas other group members rotated around to learn about and discuss findings reported by other groups. The session culminated with an open room discussion to yield final comments and recommendations. The final posters created during the morning and afternoon sessions were scanned and shared with workshop facilitators, who compiled the findings and synthesized them into the recommendations reported in this article.

## Outcomes and Recommendations

### *Key recommendations from morning session*

Three themes emerged from the activity where participants listed ''business as usual factors'' for success in academia and ''ideal factors'' participants wished could lead to success in academia: personal, professional, and external. ''Business as usual'' personal factors included work-life balance, disposition (grit), and skills (e.g., written and oral communication, networking, and organization); professional factors included the institution's prestige, research-related partnerships, capacity for mentorship, and internal dynamics; external factors included the research topic's alignment with funders' and publishers' agendas.

''Ideal'' factors with personal implications included the recruitment of underrepresented and racially minoritized (URM) faculty in cohorts; professional factors included allocating departmental resources for community-engaged work and rewards for extra work carried out by URM faculty, such as ''hidden'' or ''invisible'' service work, work on diversity and inclusion, and the mentorship of students not explicitly in their research group (Schwartz, 2012); external aspects included promotion and tenure committees' expanding their acceptance of nontraditional publications (e.g., blogs, social media, and popular press) as additional avenues for institutions to evaluate research impact in the general population and their value for community-engaged research (Edwards and Roy, 2017). For example, one breakout group wrote that the impact of research should be defined more broadly, for example, with community impact weighted greater than or equal to a journal's impact factor.

When requested to discuss the overlapping challenges of underrepresentation in environmental engineering in higher education and environmental challenges in society, respondents made a variety of suggestions. Their responses included (1) expanding undergraduate curricula to allow meaningful academic experiences with the NASEM grand challenges and (2) developing a network of graduate programs that engage and promote URM engineering students performing research addressing societal and environmental challenges. The morning concluded with a discussion of approaches to reverse underrepresentation in environmental engineering, including an in-depth conversation about the ''ideal'' factors. The need to streamline and standardize the valuation of community-engaged research and its impacts was highlighted.

### *Key recommendations from afternoon sessions*

Participants described four themes for reversing trends of underrepresentation to increase diversity and community participation for environmental and social justice (Fig. 1). Note the figure does not show the many places where challenges occur and where URM students and professionals leave this pathway.

#### Expose students to community-based research and support transitions to PhD programs.

One recommendation from the workshop was to improve efforts to recruit URM students into environmental engineering programs and support their transitions into research careers through the use of community-based projects or CBPR. The integration of service-learning (Duffy *et al.*, 2011), community engagement, and environmental justice topics into engineering education attracts URM students with altruistic values (Thoman *et al.*, 2015), culturally connected career motives (Jackson *et al.*, 2016), or an aspiration to use their careers to help others and achieve social justice (McGee and Bentley, 2017). Specifically, the use of community-based projects in the classroom can improve URM students' sense of self-efficacy and attract them to engineering and research careers (Mejia *et al.*, 2015; Gentile *et al.*, 2017).

Course-based undergraduate research experiences can help all students see how research can be directly connected to addressing real-world problems, and effectively help bring more URM students into STEM fields (NASEM, 2015). Workshop participants emphasized the benefits of course-based and noncourse-based undergraduate research and supported the use of community-based projects in first-year seminars and interdisciplinary electives. Workshop participants also suggested designing summer research programs such as the National Science Foundation's Research Experiences for Undergraduates program with specific focus on recruiting URM students.

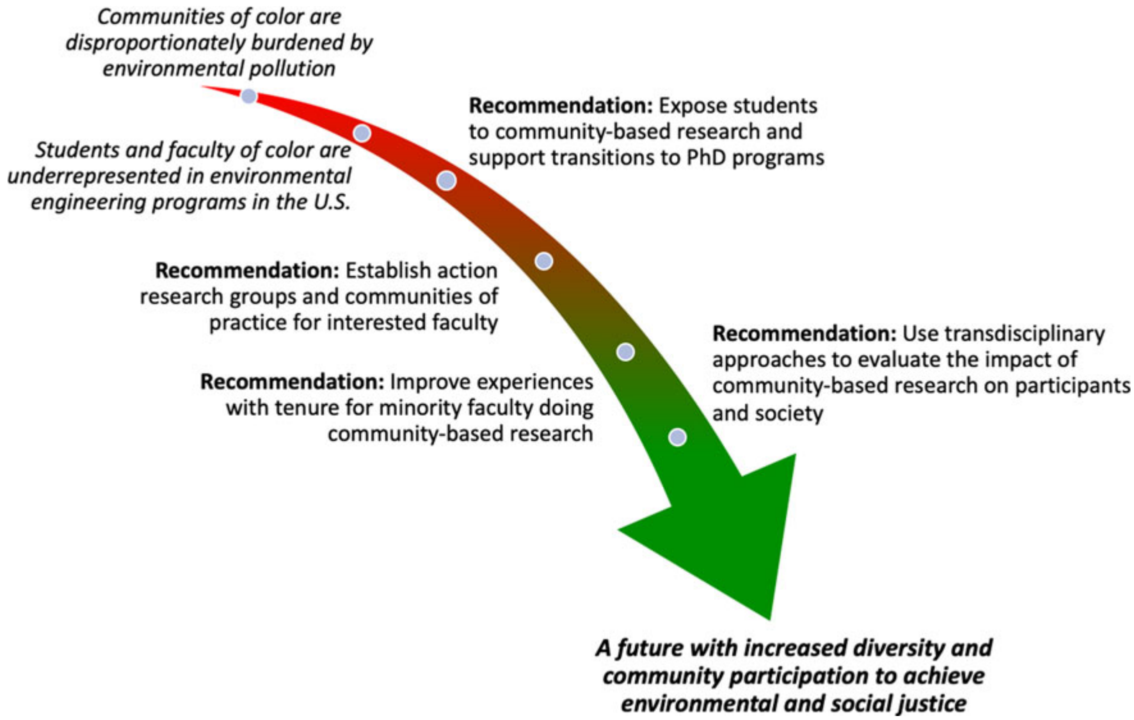


**FIG. 1.** Recommended pathway to increasing diversity and community participation to achieve environmental and social justice.

Underrepresentation in academia is caused by many factors including but not limited to implicit biases during the hiring process and in tenure decisions (Kayes, 2006; Barber *et al.*, 2020). It may also result from lower exposure of URM students to research activity at Minority Serving Institutions (MSIs) compared with non-MSIs. For instance, there are a total of 76 ABET-accredited environmental engineering programs in the United States. But, of 101 historically black colleges and universities, 345 Hispanic serving institutions, and 34 tribal colleges and universities in the United States, only 6 offer BS degrees in environmental engineering, only 8 offer master's degrees in environmental engineering, and only 7 grant PhD degrees in environmental engineering; of those institutions, only 4 have very high research activity (ASEE, 2017; IUCPR, 2018).

Conversely, 50 of 64 (78%) environmental engineering PhD programs at non-MSIs have very high research activity (IUCPR, 2018). Thus, students at MSIs are less likely to be exposed to research than their non-MSI counterparts.

University programs for undergraduate students that build research skills and support transitions into research careers could help to limit this deficit by recruiting more URM students into graduate programs in engineering. Participation in research opportunities in STEM fields at the undergraduate level has been shown to transform the career aspirations for URM students, encouraging them to pursue graduate degrees and research careers at greater rates than students who do not participate in undergraduate research (Zydney *et al.*, 2002; Russell *et al.*, 2007; Carpi *et al.*, 2017).

One model that has been successful in the biomedical sciences field is the NIH Maximizing Access to Research Careers program for undergraduate student training in academic research (MARC U-STAR), which seeks to diversify the nation's scientific workforce (Hall, 2017). This program provides research experiences, academic enhancement, mentoring, skills development, stipends, and tuition remission. Trainees also receive travel support to present at scientific conferences, which contributes to their scientist identity, enables network-building with researchers, and improves their science communication skills. Among MARC alumni monitored over 4 years, 70% were enrolled or had completed graduate degrees; of those, 29%, 14%, 12%, and 5% earned a PhD, masters, MD, and other doctorates, respectively (Hall, 2017). Similar programs in engineering disciplines should be funded to increase opportunities for engineering students at MSIs.

Integrating research into coursework and participating in CBPR can also help students succeed in professional and research careers by cultivating a culture of community-based participatory action. For example, Black PhD students in engineering were motivated to persist in their doctoral program by a sense of social responsibility to serve people and society (McGee *et al.*, 2016). Workshop participants supported the use of community-based projects in design courses such as Introduction to Environmental Engineering, Sustainable Development Engineering, Senior Capstone, and for-credit internships at nonprofit organizations, professional societies, or student clubs. Key principles of CBPR have been established (Israel *et al.*, 2017) to help researchers achieve more equitable community engagement; they should serve as guidance for all engineering faculty participating in community-based work. To support community-based projects in a classroom setting without compromising its principles, universities need long-term partnerships with community organizations, which can be performed through models such as the Sage Project (Villavicencio *et al.*, 2010).

Establish action research groups and communities of practice for interested faculty. A second recommendation from the workshop was to provide support for faculty interested in or currently using CBPR. A substantial form of support must be developed through the establishment of a community of practice to help faculty learn about topics such as community-based participatory practice and the ''funds of knowledge'' literature (Smith and Lucena, 2016; Wilson-Lopez *et al.*, 2016). Classroom action research involves the use of scientific methods to discover what works best for teachers or professors in their own classrooms to improve student learning outcomes. The use of classroom action research has been proposed as a way to improve equity in educational settings (Caro-Bruce and Klehr, 2007). Engineering faculty who integrate research opportunities and CBPR examples into their coursework may benefit by forming action research groups that use approaches such as equity analytics to study the impact of these teaching practices on closing achievement gaps related to race and ethnicity (Reinholz and Shah, 2018).

The pursuit and valuation of this type of action research during the tenure process is consistent with the teacher-scholar model (Boyer, 1990), which has already been adopted by several MSIs including many within the California State University system. In fact, there may be opportunities for MSIs to lead national efforts to redefine the way research is valued at all institutions of higher education. For instance, Sydnor *et al.* (2010) argued that historically black colleges and universities (HBCUs) are uniquely positioned to take leadership roles in bringing innovation to CBPR and advancing tenure and promotion policies.

Improve tenure and promotion experiences for minority faculty doing community-based research. A third recommendation from the workshop was to take action to increase the rate of success for minority faculty, especially those conducting CBPR. Workshop participants agreed that helping CBPR scholars be successful in tenure promotions is critical because increasing numbers of URM scholars are interested in working with communities. Workshop participants expressed concerns that earning tenure while conducting CBPR may be challenging at some institutions, and particularly for URM scholars in engineering. Obstacles such as a hostile campus climate, discrimination, and implicit bias against URM faculty have been well documented (Reyes and Halcon, 1988; Stanley, 2006; Matthew, 2016; NAS, 2020).

The use of CBPR in engineering is relatively new and the principles of CBPR may be unfamiliar to some engineering faculty, including those who serve on tenure and promotion review committees. Participants expressed concerns that a lack of understanding about CBPR by tenure and promotion review committees could hinder the appropriate valuation of its research impacts in engineering, as it has been documented for other fields (Nyden, 2003; Calleson *et al.*, 2005; Teufel-Shone, 2011; Marrero *et al.*, 2013). This would place additional burdens on URM faculty who are engaged in this type of research. Participants discussed personal challenges that have been experienced and challenges that were anticipated for minority scholars using CBPR. Key obstacles for promotion and tenure when performing such research were identified, like centering on populations that are often overlooked and ignored (Nyden, 2003; Griffin, 2020; Matias, 2020).

Historically, institutions have not always valued community-engaged research within the promotion and tenure processes; however, the NASEM report recognized ''…it is important that experts and stakeholders act in partnership to identify problems and consider alternative solutions'' (NASEM, 2018, pp. 67). Of note, although these landscape-level documents influence change in academic values, the rate and effects of change are slow to permeate individual universities and research-granting agendas at places like the National Science Foundation (NSF) and the NIH. As such, URM faculty and other faculty are performing CBPR within an outdated promotion and tenure process that does not appropriately reflect the impact of the methodological rigor and research merits of CBPR. Efforts to bring recognition to this type of research are clearly needed.

Participants identified several elements that can inform institutional evolution that helps scholars using CBPR in engineering: (1) extended time investment required by CBPR; (2) mischaracterization of CBPR as service; (3) challenges in procuring funding from traditional sources like the National Science Foundation and the National Institutes of Health when using CBPR (Hoppe *et al.*, 2019); (4) less traditional funding requiring more creativity; (5) need for multiple mentors to navigate CBPR specifics. In addition, bias in teaching evaluations that regularly work against women and faculty of color (Tuitt *et al.*, 2009) need to be recognized. Experienced simultaneously and without support, these factors can become insurmountable institutional obstacles for URM and other researchers pursuing CBPR to obtain tenure.

Transdisciplinary approaches to evaluate impact on participants and members of society. A fourth recommendation from the workshop was to explore the benefits of using transdisciplinary approaches to assess the impact of CBPR on scholars *and* communities. For example, Cook (2008) stressed the importance of evaluating the extent to which CBPR involves action that affects community-level changes. However, despite good intentions, many past CBPR efforts have experienced colossal failures (Bentley, 1994; Dodson *et al.*, 2012; Melles, 2018; Park, 2018), partially because of inadequate ethical review (Flicker *et al.*, 2007).

Workshop participants highlighted positive examples of the use of transdisciplinary approaches with engineers and social scientists for evaluating the impact of community-based research or engineering projects. For example, Wells *et al.* (2019) used research approaches from the fields of engineering and anthropology to demonstrate how a cost–benefit analysis of a proposed wastewater infrastructure program resulted in conversations about sustainability that disrupted local decision-making processes and created tension between residents voicing concerns about ownership and government officials claiming to have advanced technical expertise. The study underscored the importance of engineers and social scientists collaborating to better understand, research, and address community needs.

Despite evidence supporting the use of CBPR to recruit and retain URM students into research-based STEM programs (Mejia *et al.*, 2015; Gentile *et al.*, 2017), there is less evidence about the effect of CBPR projects in engineering on

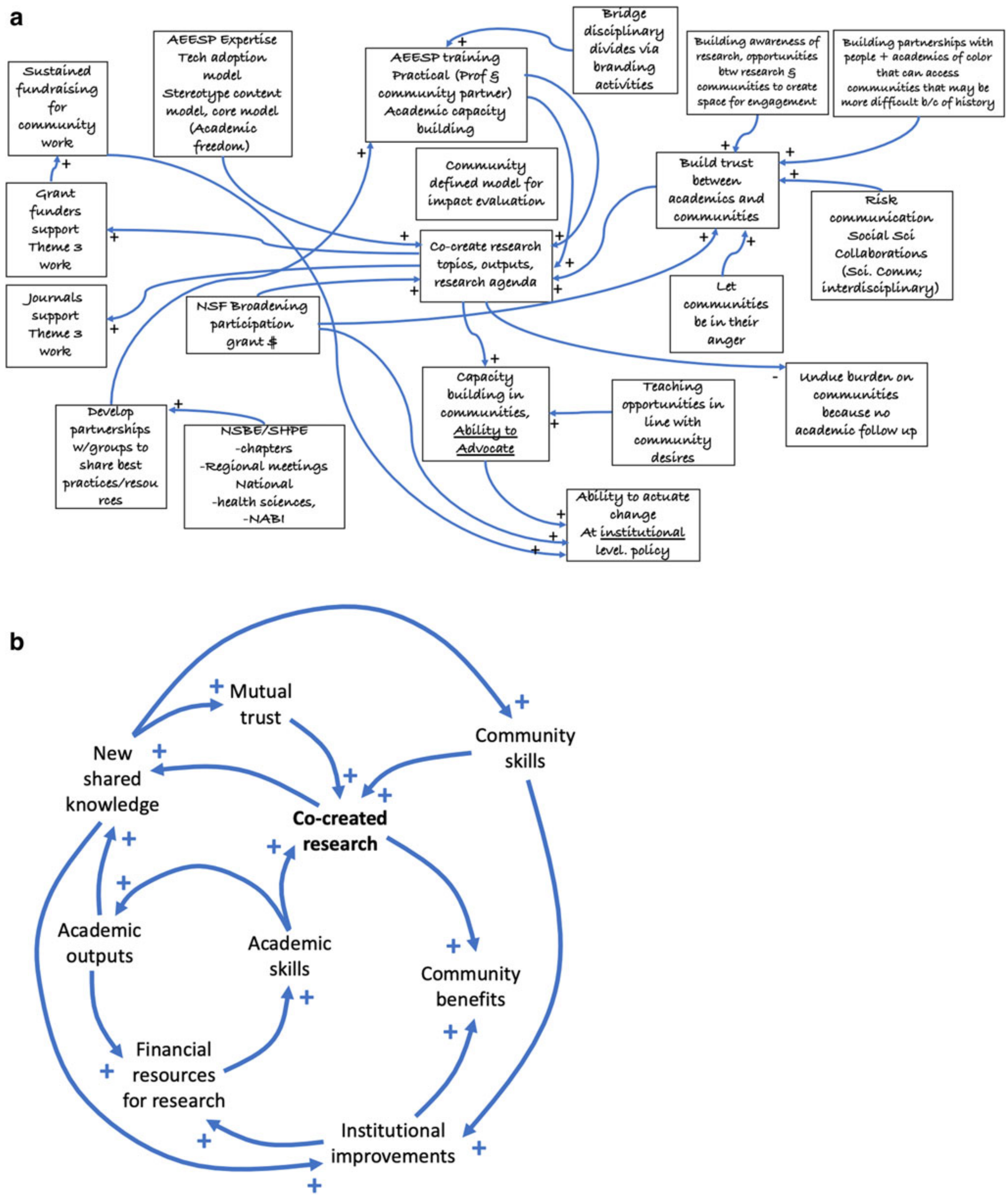


**FIG. 2.** A digitized output from one of the posters created during the workshop showing: **(a)** ideas proposed by workshop participants about how to best evaluate the impact of community-based research; and **(b)** a conceptual systems model of the causal relationships between factors that influence the co-creation of research, synthesized by the coauthors, based on the inputs from the workshop.

participant community outcomes. Cook (2008) found that 14 of 20 environmental and occupational health CBPR projects led to community-level action that improved health outcomes for community members, and that observational studies on problems posed by the community were more likely to lead to action, as were projects that incorporated the use of qualitative methods.

However, some community-based projects may have harmful outcomes for the community, despite good intentions on behalf of the researchers. For example, Park (2018) used an ethnographic approach to find that U.S. college students participating in short-term, self-funded trips to a small village in Cameroon to "improve the quality of drinking water and community health" displayed implicit beliefs about technology fixes, as well as cultural stereotypes about Western superiority, which were affirmed during the trip owing to a lack of understanding about the historical and structural context of water and health disparities in African countries. Similarly, Melles (2018) suggested that poverty becomes commodified in short-term international university trips where programs are packaged as "culturally exotic and ethical experiences for students from industrialized countries," noting that projects carried out by these groups were characterized by a lack of financial transparency, inadequate needs assessments, and insufficient participation and control by local stakeholders.

A mixture of qualitative and quantitative methods should be used to evaluate the impacts of CBPR on society. When empirical data or models (system dynamics, life cycle assessments, etc.) are robustly contextualized with qualitative perspectives (ethnographies, surveys, etc.), researchers who practice CBPR provide the foundation that can later be assessed to justify the rigor of their work.

Community-based teaching and research requires strong community partnerships, including those with K-12 schools, nonprofit organizations, governmental entities, and professional societies supporting URM groups, such as the National Society of Black Engineers, the Society of Hispanic Professional Engineers, and the American Indian Society of Engineers and Scientists. Successful CBPR efforts in engineering also involve transdisciplinary teams and long-term collaborations with communities and social scientists. An indicator of the performance of collaborations with strong community partnerships is the co-creation of research with communities (Champion *et al.*, 2017a, 2017b; Drahl, 2019; Middleton *et al.*, 2019).

Workshop participants identified factors and causal relationships (dynamics) that influence knowledge production, institutional improvement, and benefits to communities. These benefits serve as outputs to communities and academics and reinforce future collaborations for co-created research. A community-based system dynamics approach (Mui *et al.*, 2019) was used to facilitate local insights for mapping the factors and dynamics that interact to impact communities, academics, and institutions. These outputs will then produce benefits for society at-large, such as environmental and social justice. Key themes from this exercise were further distilled and used to develop a causal loop diagram (Fig. 2). Although this model does not show an exhaustive list of factors and dynamics influencing co-created research, it depicts relationships between measurable factors that can be used to evaluate the broader impacts of CBPR (e.g., on institutions, funding agencies, and communities). Three factors and dynamics that influence the co-creation of research include academic skills, community skills, and mutual trust. Developing shared knowledge is also instrumental, as it allows for enhanced mutual trust and improved community skills, thus creating a positive reinforcing loop centered around co-created research.

## Conclusions

This workshop yielded several important conclusions. The underrepresentation of Black, Hispanic, and Native American students and faculty in Environmental Engineering and other engineering disciplines needs to be addressed. First, undergraduate research programs (especially those that use CBPR) can be effective approaches for recruiting, retaining, and supporting the transition of URM students into environmental engineering research and professional careers, to reverse trends in underrepresentation in academia and achieve environmental and social justice.

Second, support is needed for faculty unfamiliar with the principles of CBPR or the "funds of knowledge" literature (Smith and Lucena, 2016; Wilson-Lopez *et al.*, 2016). Communities of practice and action research groups can be created through organizations like AEESP to facilitate the sharing of resources and experiences for faculty interested in integrating community-based participatory action into curriculum and research.

The academic community must also act to ensure that our institutions evolve so that scholars (especially URM faculty) who are effectively using CBPR may succeed in tenure promotions.

Fourth, a mixed methods approach with qualitative and quantitative facets is needed to evaluate CBPR's impact, not only on student participants, but also on the communities with whom they work.

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